

## *METHOD OF MAKING GEAR PUMP*

### **DESCRIPTION**

#### **Cross Reference to Related application**

**[Para 1]** This application is a Division of my co-pending application, Serial Number 10/605175, filed September 12, 2003 and assigned to the assignee hereof.

#### **Background of Invention**

**[Para 2]** This invention relates to an improved gear pump and more particularly to a method of making such a pump.

**[Para 3]** As is well known, gear pumps are widely used for a great variety of purposes. This is due to their ability to generate high pressures. Also these pumps generally have a compact size and shape.

**[Para 4]** In one commonly utilized type of gear pump there are a pair of intermeshing gears that are supported for rotation about parallel axes. These gears are positioned within a pumping cavity formed by a pump housing. The pump housing cavity has a generally figure 8 shape and is closed by end walls that are in confronting relationship to the flat end faces of the gears. Passages permit the flow of the pumped fluid to and from the space between the gears. Because of machining problems with the prior art type of pumps and their manufacturing methods it has been the practice to interpose bearing end plates between the gear end faces and the pump housing.

**[Para 5]** For example, published Japanese Patent Application Hei 08-93653 shows a typical prior art pump of this type. The pump main housing member is formed with the pumping chamber by a machining operation through one end face thereof. At the bottom of this cavity, a fillet will be formed of

machining necessity. Thus the peripheral edge of the gears must be spaced from this projecting area of the pump housing to avoid interference. This spacing can and is accomplished in part by chamfering the edges of the gear teeth. This however leaves a void area where leakage of the pumped fluid will occur and thus the efficiency of the pump is decreased.

**[Para 6]** The amount of chamfering required can be reduced by utilizing bearing end plates that engage the flat ends of the gears as shown in FIG. 3 of the noted published Japanese Patent Application. However that adds to the size and cost of the pump. In addition the end plates themselves introduce clearances and areas where leakage can and does occur.

**[Para 7]** It is, therefore, a principle object of this invention to provide an improved, simplified pump manufacturing methodology.

**[Para 8]** It is a further object of this invention to provide an improved, pump manufacturing methodology that offers higher efficiencies and more compact construction than heretofore possible.

## Summary of Invention

**[Para 9]** This invention is adapted to be embodied in an intermeshing gear pump and more particularly to a method of manufacturing such a pump. The pump is comprised of an outer housing defining a pumping cavity in which a pair of intermeshing gears are journaled on respective shafts for pumping a fluid from a fluid inlet to the pumping cavity to a pumping outlet from the pumping cavity. The intermeshing gears having end faces extending perpendicularly to the rotational axes of the gears at opposite sides of the gears. The outer housing comprises a main body part and at least one separate end plate affixed thereto. The main body part has an opening extending axially therein that defines a portion of the pumping cavity facing the circumferential peripheral surfaces of the gears. The end plate closes a respective side of the main body part opening. A fastener arrangement affixes the end plate and the main body part together. The method comprising the steps of placing a pair of plates in abutting relationship. The abutting plates

are held against transverse movement relative to each other. A pair of holes are drilled through the plates from one side of one of the plates and ending through the oppositely facing side of the other of the plates so that any burrs formed by the drilling operation will be formed on the oppositely facing side of the other of the plates. Then a cavity is machined in at least the oppositely facing side of the other of the plates of sufficient size to form the pumping cavity and in an area encompassing that of the previously drilled holes to remove any burrs formed by the drilling operation and form the main body part. Then the one plate is placed and affixed against the main body part in closing relation to the pumping cavity formed therein to form the end plate therefor.

### **Brief Description of Drawings**

**[Para 10]** FIG. 1 is a side elevational view of a marine propulsion unit having a tilt and trim unit powered by a fluid pump embodying the invention and manufactured in accordance with the invention which propulsion unit is shown attached to the transom of a watercraft hull, shown partially and in section.

**[Para 11]** FIG. 2 is an enlarged elevational view of the tilt and trim unit broken away to show the pump.

**[Para 12]** FIG. 3 is a cross sectional view of the pump taken through the gear axes.

**[Para 13]** FIG. 4 is a top plan view of the pump with a portion of the top cover broken away to more clearly show the construction.

**[Para 14]** FIG. 5 is an enlarged view looking in the same direction as FIG. 4 but showing only the connection between one of the pump gears and its shaft.

**[Para 15]** FIG. 6 is a cross sectional view taken along the same plane as FIG. 3, but showing a phase of the manufacturing process.

### **Detailed Description**

**[Para 16]** Referring now in detail to the drawings, FIGS. 1 and 2 show a marine propulsion system, indicated generally by the reference numeral 11, as this is a typical, but not the only, use of the invention. In the illustrated embodiment, the propulsion system 11 is comprised of an outboard motor 12 and a hydraulically operated tilt and trim unit 13, that is shown in most detail in FIG. 2.

**[Para 17]** Referring now to FIG. 1, the outboard motor 12 is comprised of a power head 14 that contains a powering internal combustion engine that is not shown because of its containment in a surrounding protective cowling. The engine drives a drive shaft (not shown) that is journalled in a drive shaft housing 15 and into a lower unit 16 where it drives a propulsion device such as a propeller 17.

**[Para 18]** The drive shaft housing 15 is connected to a steering shaft (not shown) that is journalled for steering movement about a generally vertically extending axis in a swivel bracket 18 in a manner well known in the art. The swivel bracket 18 is pivotally connected to a clamping bracket 19 by a pivot pin 21, in a manner that is also well known in the art. The clamping bracket 19 is suitably connected to the transom of a watercraft hull 22, operating in a body of water 23.

**[Para 19]** Except for its powering pump, to be described shortly, the function and operation of the tilt and trim unit 13 is as well known in the art to trim or tilt the outboard motor 12 up in the direction of the arrow U or down in the direction of the arrow D. In addition the tilt and trim unit 13 may function as a shock absorber to permit the outboard motor 12 to "pop up" when an underwater obstacle is met and to return to the trim adjusted position when it is cleared.

**[Para 20]** Referring now primarily to FIG. 2, the tilt and trim unit 13 is comprised of a hydraulic cylinder housing, indicated generally at 23, having one end pivotally connected to the clamping bracket 19 on the hull 22 by a pivot shaft 24. The cylinder housing 23 forms a cylinder bore 25 that is divided by a piston 26 into first and second pressure oil chambers 27 and 28. A piston rod 29 is fixed to the piston 26 and extends through the chamber 28 and out

of the cylinder housing 23 where it is connected by a pivot shaft 31 to the swivel bracket 18. By pressurizing the chamber 27 and exhausting the chamber 28 the outboard motor 12 will move for upward tilting action U. Conversely pressurizing the second pressure oil chamber 28 and exhausting the chamber 27 will effect the outboard motor 12 to move downward for returning action D. The construction and operation of the unit 13 is well known in the art and thus further description except for its pump, next to be described, is not believed necessary. This is particularly true since the use of the pump is not so limited.

**[Para 21]** The pump, indicated generally by the reference numeral 32, comprises an intermeshing gear pump supported by threaded fasteners 33 on the cylinder 23, a reversible electric motor 34 for driving the gear pump 32, and, indicated generally at 35 for introducing oil which is a pressurized fluid delivered from the gear pump 32 driven by the electric motor 34 into the cylinder 23.

**[Para 22]** The gear pump 32 is supported by the threaded fasteners 33 on the cylinder 23 and comprises a housing assembly 30, made of an iron-based sintered metal, constituting the outer shell of the gear pump and defining a pumping cavity, indicated generally by the reference numeral 36, see now additionally FIGS. 3-5. A pair of spur gears 37, 38 are contained in the pumping cavity 36 with their axial centers 39, 41 disposed parallel, and meshing with each other. Shaft receiving holes 42, 43 are formed in the housing assembly 30 and the gears 37, 38 on the axial centers 39, 41. Supporting shafts 44, 45 are inserted in these shaft holes 42, 43 and journalled at both ends on the housing assembly 30 for supporting these gears 37, 38 for rotation about the axial centers 39, 41. At least either one of these supporting shafts 44, 45 is driveably connected to the reversible electric motor 34. The gears 37, 38 are of the same shape and the same size and their flat end faces are flush with each other.

**[Para 23]** The internal surface of the pumping cavity 36 is formed by a pair of inside cylindrical surfaces 46, 47 that extend parallel to the axial centers 39, 41 and directly face the two gears 37, 38 in close proximity to the outside

surfaces thereof. This forms a generally figure 8 shaped recess facing directly the outside circumferential surfaces of the two gears 37, 38 in close proximity thereto.

**[Para 24]** The housing assembly 30 is made up of first, second and third pieces 48, 49, 51, each of a flat plate-like shape. These pieces 48, 49 and 51 are stacked together in this order in direct contact with the piece 49 forming the main pump body and the pieces 48 and 49 forming upper and lower end closures therefore. Threaded fasteners 52 detachably fix these first, second and third pieces 48, 49, 51 together. However locating pins 53 position the first, second and third pieces 48, 49, 51 to each other prior to the fixing by the threaded fasteners 52. In addition the threaded fasteners 33 fix the first, second and third pieces 48, 49, 51 together when the gear pump 32 is supported on the cylinder 23, and thus have the same function as the threaded fasteners 52.

**[Para 25]** The threaded fasteners 33 pass through holes 54 provided through the housing assembly 30 parallel to the axial centers 39, 41 and are screwed into tapped openings formed in the cylinder 23. In a similar manner the threaded fasteners 52 pass through holes 55 provided through the first and second pieces 48, 49 parallel to the axial centers 39, 41, and are received in tapped openings 56 formed in the third piece.

**[Para 26]** The locating pins 53 are positioned in aligning holes 57 provided in the first, second and third pieces 48, 49, 51 be parallel to the axial centers 39, 41. As already noted and insertion of the locating pins 53 into the aligning holes 57 allows the first, second and third pieces 48, 49, 51 to be positioned accurately to each other.

**[Para 27]** A coupling device, indicated generally at 58, is provided for coupling the gears 37, 38 and the respective support shafts 44, 45 so that the gears 37, 38 rotate with the support shafts 44, 45, respectively. The coupling means 58 is shown best in FIG. 5 and comprises coupling grooves 59 formed on one flat face of the gears 37, 38 adjacent the housing piece 48. These grooves 59 receive the ends of coupling pins 61 that penetrating radially through suitable openings formed in the support shafts 44, 45. The pins 61

are inserted in the coupling grooves 59 with a small play in a clearance-fit relation.

[Para 28] As shown in FIG. 3, the lower ends of the shafts 44 and 45 and the upper ends of the shaft holes 42 and 43 are chamfered significantly to facilitate assembly.

[Para 29] Referring now primarily to FIG. 3 and also FIG. 4, the oil introducing device and reservoir 35 comprises a pair of oil passages 62 and 63 are formed in lower end plate 51 of the housing assembly 30. The oil passage 62 allows the area of one of two portions of the pumping cavity 36 formed on both sides of the mutual meshing portion of the gears 37, 38 to communicate with the outside of the housing assembly 30. The other oil passage 63 allows the other of two portions of the pumping cavity 36 to communicate with the outside of the housing assembly 30. The passages 62 and 63 communicate with these portions of the pumping cavity 36 through recesses 64 and 65, respectively, formed in the lower face of the main housing portion 49.

[Para 30] In addition to the oil passages 62 and 63, the oil introducing device 35 comprises still another two oil passages 66 and 67 for providing communication of the recesses 64 with a reservoir 68 of the device 35. Ball type check valves 69 in enlargements of the lower end plate passages 66 and 67 permit the drawing of make up fluid from the reservoir 68.

[Para 31] The passage 62 communicates with the chamber 27 of the cylinder 23 through a conduit 71 which is external of the pump housing 50. In a like manner the passage 63 communicates externally with the cylinder chamber 28 through a conduit 72. As is well known in the art, shuttle valves 73 are provided in the passages 71 and 72 to permit reverse flow. Pressure relief valves 74 and 75 are provided in the conduits 71 and 72 respectively for limiting the maximum pressure exerted in the cylinder chambers 27 and 28, respectively. There are also provided a pair of pressure relief valves 76 between the shuttle valves 73 and the reservoir 68 for a similar purpose.

[Para 32] As seen in FIGS. 3 and 4, when the electric motor 34 is operated in the trim up direction to rotate the gears 37, 38 in the trim up directions U, respectively, remembering that the gears 37, 38 are rotated the opposite

directions due to their intermeshing relationship, pressure oil is delivered from the gear pump 32 passages 64 and 62. This pressurized oil is supplied to the first pressure oil chamber 27 of the cylinder 23 through the oil introducing device 35, as shown in these figures by the solid lines, so that the cylinder 23 extends to move the outboard motor 12 for upward tilting action U. Since the external circuitry is well known in the art it is not believed necessary to describe its operation any further. It should also be remembered that this environment is only one of many possible uses for the pump 32.

**[Para 33]** On the other hand, when the electric motor 34 is operated in the reverse direction to rotate the gears 37, 38 in the reverse directions D, respectively (gears 37, 38 are rotated reversely in the directions opposite to those of the previous case), pressure oil delivered from the gear pump 32 is supplied to the second pressure oil chamber 28 of the cylinder 23 through the oil introducing device 35, as shown in Figs. 1 and 4 by single dot and dash lines, so that the cylinder contracts to move the outboard motor 12 for downward returning action D. Again, since the external circuitry is well known in the art it is not believed necessary to describe its operation any further.

**[Para 34]** Next, by principal reference to FIG. 6, which should also be compared to FIG. 3, a method of forming the gear pump 32 will be described, as this constitutes an important feature of the invention. In FIG. 6, work pieces that will eventually become the main body housing 49, and the upper and lower end closures 48 and 51. These work pieces before machining are indicated in FIG. 6 by the reference numerals 81, 82 and 83, respectively. That is the work piece 81 will become after machining the main body housing 49 and the work pieces 82 and 83 will become the upper and lower end closures, respectively.

**[Para 35]** First, second and third work pieces 81, 82, 83 are formed each having the same thickness and size as the respective final housing pieces 48, 49, 51. However, for reasons that will shortly become apparent, the work pieces are initially stacked and retained in an order different from their final assembled positions. They are stacked together in the order of the second, the

first and the third work pieces 82, 81, 83 in direct contact and fixed together by a suitable mechanism.

**[Para 36]** Then, the shaft holes 42, 43 are machined with a tool such as a pair of drills<sup>84</sup> from the lower side of the third work piece<sup>83</sup> through the first work piece<sup>81</sup> toward the upper side of the second work piece<sup>82</sup>. In this case, when the shaft holes 42, 43 are drilled in the second work piece<sup>82</sup>, burrs indicated at 85 are normally produced at the edges of the holes on the ending side of the drilling operation. However, the shaft holes 42, 43 are not necessarily machined through the upper side of the second work piece<sup>82</sup> to practice the invention.

**[Para 37]** Then, in the second work piece<sup>82</sup> is machined, with another cutting tool to form the pumping cavity<sup>36</sup> having a constant cross-sectional shape in the direction of depth, through the entire thickness of the second work piece<sup>82</sup>. This machining is preferably continued into the first work piece<sup>81</sup> on the side adjacent the second work piece<sup>82</sup> to form a recess 86 of the same cross-section in shape and size as the pumping cavity<sup>36</sup> but preferably of lesser axial length. In this case, the burrs 85 are automatically eliminated in association with the formation of the pumping cavity<sup>36</sup>.

**[Para 38]** The bolt through holes 54 and locating pin holes 57 are formed in the first, second and third work pieces 81, 82, 83 to form the first, second and third pieces<sup>48, 49, 51</sup>. These pieces are then separated to perform the threading operation in the piece 83 and the oil passage drilling operation and such other machining in the main body work piece 82 and lower end closure work piece 83 as required.

**[Para 39]** Then the resulting pump pieces are rearranged in their final order. After that, the gears 37, 38, support shafts 44, 45, coupling means 58 and knock pins 56 are incorporated in these pieces and then the first, second and third pieces<sup>48, 49, 51</sup> are put together directly in this order and fixed with the threaded fasteners<sup>52</sup>. The formation of the gear pump 32 is thereby completed.

**[Para 40]** Because of this arrangement, the inside surfaces 46, 47 of the pumping cavity<sup>36</sup> face directly the outside surfaces of the gears<sup>37, 38</sup>. As

previously noted, in the prior art, sliding plates are provided between the end faces of the gears 37, 38 and the inside surfaces 46, 47 of the pumping cavity36. That is not necessary here since no fillet results at the bottom of the pumping cavity 36. Therefore in this invention, the size of the housing assembly30 can be decreased, that is, the size of the gear pump 32 can be decreased.

**[Para 41]** Therefore, in forming the housing assembly30, a hole having the same cross-section in shape and size as the pumping cavity36 when viewed in the direction of the axial centers 39, 41 is first machined through a flat plate member of the same thickness as the second piece49 to form the second piece49. Then the first, second and third pieces48, 49, 51 are put together in this order, so that the inside surfaces 46, 47 of the pumping cavity36 are defined by the first and third pieces48, 51, and the inside circumferential surface 38 of the pumping cavity36 by the second piece49, that is, the piece30 containing the pumping cavity36 is formed.

**[Para 42]** In this case, it can be ensured more reliably in association with the formation of the pumping cavity36 that corners of the opening ends of the pumping cavity36 open to the outsides from the second piece 49 are shaped to be right angular. Therefore, the corners of the pumping cavity36 defined by the inner surfaces 46, 47 and the inside circumferential surface 38 can be each formed into a right angular shape more reliably. Thus, if the peripheral corners of the gears37, 38 are shaped to be right angular and the inside corners and the peripheral corners are fitted together, clearances between the peripheral corners and the inside corners can be significantly decreased compared with when they are shaped in arcs and fitted together.

**[Para 43]** Therefore, partial return of pressure oil from the delivery side to the suction side through the foregoing clearances in the prior art constructions is prevented. Thus during operation of the gear pump 32 the pressure of the pressure oil delivered from the gear pump 32 can be increased to a sufficiently high value. Also, because the mating surfaces of the first, second and third housing pieces48, 49, 51are flat these outside surfaces can be easily formed with high accuracy, which allows easy formation of the gear pump 32.

**[Para 44]** Also as described above, the gears 37, 38 are formed with shaft holes 42, 51 on the axial centers 39, 41, and the support shafts 44, 45 are inserted in the shaft holes 42, 43. Therefore, since it is ensured that corners defined by the outside surfaces of the gears 37, 38 and the outside circumferential surfaces of the support shafts 44, 45 can be shaped to be right angular. Thus the corners of the opening ends of openings of the shaft holes 42, 43 into to the pumping cavity 36 are shaped to be right angular and the corners of the gears and those of the opening ends of openings of the shaft holes are fitted together, clearances between these corners can be significantly decreased compared with when they are formed into arcs and fitted together.

**[Para 45]** Therefore, partial return of pressure oil from the delivery side to the suction side through the foregoing clearances is prevented more reliably during operation of the gear pump 32, so that the pressure of the pressure oil delivered from the gear pump 32 can be increased to a sufficiently high value.

**[Para 46]** Also as described above, gears 37, 38 and support shafts 44, 45 are rotatable relative to their axial centers 39, 41, and coupling means 58 is provided for coupling the gears 37, 38 and the support shafts 44, 45 without fixing to each other such that said gears 37, 38 rotate with said support shafts 44, 45. Therefore little play is produced between the gears 37, 38 and the support shafts 44, 45, even if a forming error is produced in the degree of right angularity between the inside surfaces 46, 47 of the pumping cavity 36 and the axial centers 39, 41 of the support shafts 44, 45, this error is absorbed by the foregoing play, and the inside surfaces 46, 47 of the pumping cavity 36 can be brought close to the gears 37, 38 throughout their outside surfaces in close contact, so that clearances between the inside surfaces 46, 47 of the pumping cavity 36 and the outside surfaces of the gears 37, 38 can be significantly decreased.

**[Para 47]** Thus it should be readily apparent that a pump configured and manufactured as described provides a high output and compact configuration. Those skilled in the art will readily understand that the foregoing description is of preferred embodiments of the invention and that various changes and

modifications may be made without departing from the spirit and scope of the invention, as defined by the appended claims.